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ANTHROPOMETRY OF THE HUMAN EAR

(A PHOTOGRAMMETRIC STUDY OF USAF FLIGHT PERSONNEL)

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Foreword

This study was done under Project 7184, "Human Performance in Advanced Systems," Task 718408, "Anthropology for Design." It was a joint effort on the part of the Anthropology Branch, Human Engineering Division, Aerospace Medical Research Laboratories, and of Antioch College, Yellow Springs, Ohio. Project scientists were Mr. Milton Alexander for the Anthropology Branch, and Mr. Lloyd L. Laubach for Antioch College under contracts AF 33(615)-1101 and F 33615-67-C-1310, monitored by Mr. Charles E. Clauser. All photogrammetric measurements were taken by the aforementioned project scientists.

The authors are grateful to Miss Margaret E. Marshall and Edmund Churchill, Anthropology Research Project, Antioch College, who contributed much time to the statistical analysis of the data. The diligent efforts of Messrs. Peter A. Colbert and Mark Reed, Antioch College, during the measurement phase of the survey, are greatly appreciated.

Mrs. M. J. Kennedy prepared the drawings for the report.

Mr. Charles E. Clauser, Chief of the Anthropology Branch, deserves the authors' thanks for his valuable suggestions during every phase of the study. Dr. Melvin J. Warrick is hereby acknowledged for his significant contributions and critical review of the manuscript. Captain John C. Henninger, Anthropology Branch, deserves credit for his aid in formulating the methodology for data application.

The PhotoMetriC Corporation, New York, New York, developed and manufactured the photogrammetric system employed during this study. Mr. Carlysle Richard, PhotoMetriC Corporation, was very helpful in supplying data concerning the photogrammetric system during the data analysis phase.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory
Aerospace Medical Research Laboratories

Abstract

A technique was developed that enables precisely specified ear dimensions to be measured directly from PhotoMetriC slides. Summary statistics for each of the various ear dimensions are presented for a sample of 500 subjects randomly chosen from a total series of 2236 photographic slides collected during the 1957 Anthropometric Survey of USAF Male Flying Personnel. Regression equations for predicting various ear dimensions from Ear Length and Ear Breadth are presented. A complete intercorrelation matrix for all variables studied in this research is also shown. The reliability and objectivity of the technique are discussed.

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SECTION I.
Introduction

A chief focal point of discomfort in protective headgear is in the area of the wearer's ears. Ill-fitting earcups cause annoying pressure points that result in pain and discomfort which increase with the passage of time. Temporary relief is sometimes afforded by "shifting" an earcup when it can be reached as in open-type headgear such as low-altitude protective helmets. This procedure is prevented, however, in enclosed helmets, such as partial- and full-pressure helmets, which seal directly to the neckring of the garment.

The purpose of the present study is to supplement existing anthropometric data of the human ear and ultimately to improve sizing and design of earcups. The standard measurements of the ear, such as Ear Length, Ear Breadth, Ear Length Above Tragion, and Ear Protrusion, have traditionally been a part of military anthropometric surveys (ref 3, 4). These measurements have served as the basic design criteria for earcups for the past 17 years. The present study is designed to furnish supplementary data of those areas of the ear not covered by the above measurements. Using these data, it should be possible to design "contoured" earcups that will cover the human ear comfortably with a minimum of surplus space. A reduction in weight of the cups and more efficient acoustical reception should also result.

SECTION II.
Photogrammetric Method

The most expeditious method of measuring the human ear is by photogrammetry. Measuring the "live" ear presents many obvious disadvantages. Securing large numbers of subjects, distortion of the soft tissues of the "live" ear during measurement, maintaining proper orientation of the head for several minutes, etc., were only a few of the reasons for using the photogrammetric technique. The photographic method chosen to accomplish the survey was developed and manufactured by the PhotoMetriC Corporation of New York. This particular system has been a valuable tool in conducting certain specialized surveys by the Anthropology Branch since 1957 (ref 1, 9). It consists of a fixed installation of mirrors and electronic flash units. The mirrors are arranged geometrically so that four views of a human subject are concurrently visible on a single exposure of film. The four photographic views of each subject are recorded on a single square negative and subsequently processed by the PhotoMetriC Corporation and returned to the user as glass positive lantern slides. The glass lantern slide retains with considerable accuracy the dimensions of the body images as they were on the original negative (ref 6). A special projector and mirror are used to enlarge the glass slide to one-half life size on a ground glass translucent screen. Measurements may then be taken directly from the screen.

SECTION III.

Magnification Distortion Factor

Problems of distortion in photogrammetry have been discussed by Gavin, Washburn, and Lewis (ref 7) and Tanner and Weiner (ref 12). Their method for calculating magnification differences is discussed by Seaford (ref 11) . . .

> The distance from the nodal point of the camera lens to the plane of the operation is first determined. This figure then is divided by the overall distance between the nodal point of the camera lens to the point of zero magnification distortion (9271 mm in the PhotoMetriC system). The quotient yields the percentage of the measurement of the photographic image which is represented by the real measurement. Therefore, in the PhotoMetriC system, the real counterpart of any measurement taken on a plane 10 cm towards the camera from the zero point is 98.92% of the magnified dimension. Thus, for every 10 cm closer to the camera, there is a magnification distortion of 1.08%.

In the present study, the seated profile pose was used, presenting a clear view of the left ear of each photographed subject. We think the differences between the left and right ear would be very small and for purposes of this study insignificant. A literature search has failed to indicate anything to the contrary. It was necessary to apply a 0.76% magnification factor to each measurement since the ear is located about 7 cm (approximately ½ the mean Bitragion Diameter (ref 4)) closer to the nodal point of the camera lens than the zero magnification point.

SECTION IV.
The Sample

In the summer of 1957, the PhotoMetriC® system was used in conjunction with an anthropometric survey of 2236 male flying personnel at six different Air Force bases in the eastern portion of the United States. At each base the PhotoMetriC camera and mirrors were firmly installed in proper geometric location. Before photographing each subject in the seated and standing positions, stature, weight and selected body circumferences were measured. Anatomical landmarks were located and marked on each subject for future reference on the projected photographic image (ref 11).

For the present study a sample of 500 slides were randomly selected from the total series of 2236. Table I indicates that the subsample of 500 subjects compares favorably for age, stature and weight with the total sample of the 1957 USAF anthropometric survey and also with the recently completed 1967 USAF anthropometric survey of flight personnel in which 2420 male subjects were measured at seventeen Air Force bases across the United States.[1] Based on considerable experience, we believe that the data included in this report are applicable to ground as well as flight personnel.

TABLE I

COMPARISON OF THE STUDY GROUP WITH THE 1957 AND 1967 USAF ANTHROPOMETRIC SURVEY SAMPLES OF FLIGHT PERSONNEL

	Study Sample (N=500)		1957 USAF Sample (N=2236)		1967 USAF Sample (N=2420)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age*	28.32	6.06	27.95	5.04	30.03	6.31
Stature	176.08	5.96	176.04	6.34	177.34	6.19
Weight	75.79	9.96	75.46	10.35	78.74	9.73

*Age is in years; stature in centimeters; weight in kilograms.

[1]Anthropology Branch and Antioch College, Unpublished Data from 1967 USAF Anthropometric Survey, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, (Report in Preparation).

SECTION V.

Measuring Technique

After projecting and aligning the sample slide on the translucent screen, the baselines are marked in the following manner:

Step 1 – Draw a straight line along the longest axis of the ear. This line is designated A in figure 1.

Step 2 – Draw a line parallel to A and in contact with the most posterior edge of the helix. This line is designated B in figure 1.

Step 3 – Draw a line parallel to A and B and in contact with the most anterior edge of the auricula. This line is designated as C in figure 1.

Step 4 – Draw a horizontal line across the auricula of the ear which terminates at C at the level of landmark Tragion. This line is designated as D in figure 1.

After the baselines are marked, the measurements are taken as follows:

Step 5 – With a clear plastic ruler, measure Ear Length along Line A from the superior to the inferior edges of the ear.

Step 6 – Measure Ear Length above the Plane of Tragion along Line A from Line D to the superior edge of the ear.

Step 7 – To determine Ear Breadth measure the distance between Lines B and C.

Step 8 – Using a clear plastic protractor (modified to indicate angles at 15° intervals and millimeter distances along the angle lines), measure the distances from the zero point (point designated by the intersection of Lines C and D) to the margin of the ear at 15° intervals up to 165°. These angular ear dimensions have been given the name Tragus Radius.

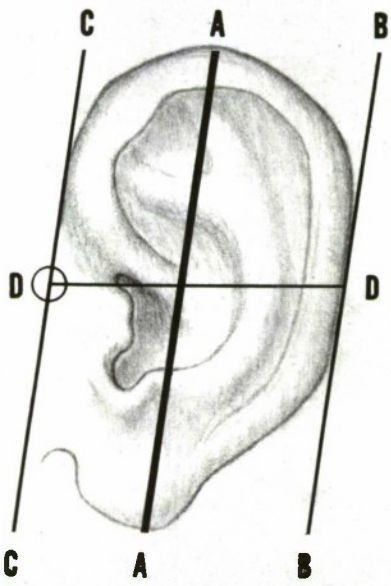


Figure 1. Baselines Used for Various Ear Clearance Dimensions

SECTION VI.

Survey Results

The 500 randomly selected PhotoMetriC slides were measured on separate occasions by both investigators. The measurements taken from the PhotoMetriC slides were measured to the nearest half-millimeter. The correction factor for distortion was then applied to the resulting values. The two values that were obtained for each photogrammetric measurement were then averaged. Therefore, the values reported for the sample of 500 subjects are averaged values from two investigators measuring the same PhotoMetriC slides on two separate occasions. The reliability and objectivity of this technique is discussed and presented in the Appendix.

On the following pages summary statistics including the mean, standard error of the mean, standard deviation, standard error of the standard deviation, range, coefficient of variation, skewness, sample size and selected percentiles are presented for the measurements of Ear Length, Ear Breadth, Ear Length Above Plane of Tragion and the eleven Tragus Radii angular measurements. Regression equations for the prediction of the Tragus Radii angular dimensions are also presented together with the coefficient of multiple correlation (R) and the standard error of estimate. In some procedures a simple regression equation based on the correlation between the desired Tragus Radius dimension and either Ear Length or Ear Breadth is nearly as accurate in predicting the unknown value as the multiple regression equation. The intercorrelation matrix for all of the variables studied is presented in table V.

The computation of the statistical measures presented in this report were performed on the IBM 7094 electronic computer. For a discussion of the procedures and techniques used in the statistical computations, the reader is referred to the following sources: *Anthropometric Survey of Turkey, Greece and Italy*, pp. 23-34 (ref 5) and "Statistical Considerations," Chapter 3 in *Human Development*, pp. 40-75 (ref 2).

EAR LENGTH

Summary Statistics		
Mean	67.1 mm	2.6 in
SE of the Mean	0.2 mm	0.0 in
Standard Deviation (SD)	4.5 mm	0.2 in
SE of the SD	0.1 mm	0.0 in
Range	53.8 mm - 79.7 mm	
	2.1 in - 3.1 in	
Coefficient of Variation	6.7%	
Skewness	0.17	
Sample Size	500	

Percentile Values		
%	*mm*	*in*
1	57.9	2.3
2	58.7	2.3
3	59.3	2.3
5	60.1	2.4
10	61.4	2.4
15	62.4	2.5
20	63.1	2.5
25	63.9	2.5
30	64.5	2.5
35	65.1	2.6
40	65.7	2.6
45	66.3	2.6
50	66.9	2.6
55	67.5	2.7
60	68.1	2.7
65	68.7	2.7
70	69.4	2.7
75	70.1	2.8
80	71.0	2.8
85	71.9	2.8
90	73.1	2.9
95	74.8	2.9
97	75.8	3.0
98	76.6	3.0
99	77.7	3.1

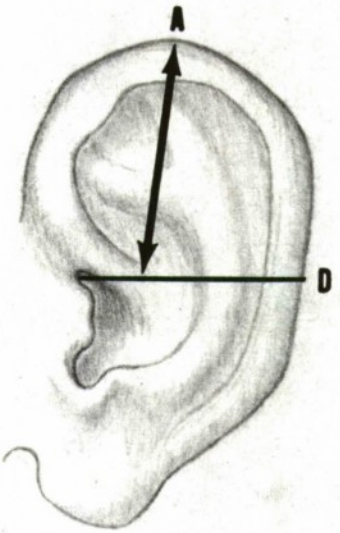
EAR BREADTH

Summary Statistics		
Mean	34.5 mm	1.4 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.9 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	27.4 mm - 42.8 mm	
	1.1 in - 1.7 in	
Coefficient of Variation	8.4%	
Skewness	0.16	
Sample Size	500	

Percentile Values

%	*mm*	*in*
1	27.9	1.1
2	28.6	1.1
3	29.0	1.1
5	29.7	1.2
10	30.6	1.2
15	31.3	1.2
20	31.9	1.3
25	32.3	1.3
30	32.8	1.3
35	33.2	1.3
40	33.6	1.3
45	33.9	1.3
50	34.3	1.4
55	34.7	1.4
60	35.1	1.4
65	35.5	1.4
70	35.9	1.4
75	36.4	1.4
80	36.9	1.5
85	37.5	1.5
90	38.3	1.5
95	39.4	1.6
97	40.2	1.6
98	40.7	1.6
99	41.6	1.6

EAR LENGTH ABOVE PLANE OF TRAGION



Summary Statistics		
Mean	32.0 mm	1.3 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.5 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	25.4 mm - 38.3 mm	
	1.0 in - 1.5 in	
Coefficient of Variation	8.0%	
Skewness	–0.04	
Sample Size	500	

Percentile Values		
%	*mm*	*in*
1	26.2	1.0
2	26.6	1.1
3	27.0	1.1
5	27.5	1.1
10	28.4	1.1
15	29.0	1.1
20	29.5	1.2
25	30.0	1.2
30	30.4	1.2
35	30.8	1.2
40	31.2	1.2
45	31.5	1.2
50	31.9	1.3
55	32.2	1.3
60	32.6	1.3
65	33.0	1.3
70	33.3	1.3
75	33.7	1.3
80	34.2	1.3
85	34.6	1.4
90	35.2	1.4
95	36.0	1.4
97	36.5	1.4
98	36.9	1.5
99	37.4	1.5

TRAGUS RADIUS 15°

Summary Statistics		
Mean	35.0 mm	1.4 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.9 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	27.4 mm - 43.8 mm	
	1.1 in - 1.7 in	
Coefficient of Variation	8.3%	
Skewness	0.21	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 15 Degrees*

.45 (Ear Length) + .05 (Ear Breadth) + 3.08

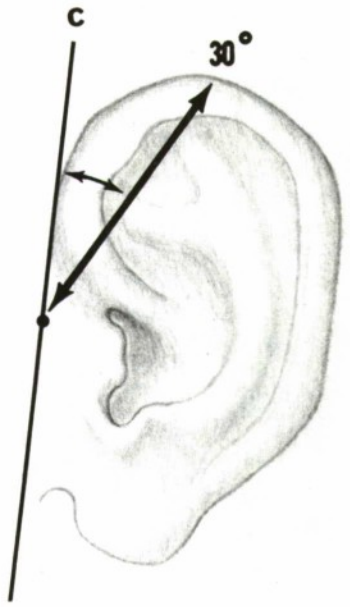
R = .72

SE of Estimate = 2.01

*Regression equation values presented in metric units only.

Percentile Values		
%	*mm*	*in*
1	28.8	1.1
2	29.4	1.2
3	29.8	1.2
5	30.3	1.2
10	31.2	1.2
15	31.8	1.3
20	32.3	1.3
25	32.8	1.3
30	33.2	1.3
35	33.6	1.3
40	34.0	1.3
45	34.3	1.4
50	34.7	1.4
55	35.1	1.4
60	35.5	1.4
65	35.9	1.4
70	36.4	1.4
75	36.9	1.5
80	37.4	1.5
85	38.0	1.5
90	38.8	1.5
95	39.9	1.6
97	40.6	1.6
98	41.1	1.6
99	41.7	1.6

TRAGUS RADIUS 30°



Summary Statistics

Mean	39.0 mm	1.5 in
SE of the Mean	0.2 mm	0.0 in
Standard Deviation (SD)	3.3 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	30.9 mm - 49.8 mm	
	1.2 in - 2.0 in	
Coefficient of Variation	8.4%	
Skewness	0.20	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 30 Degrees*

.39 (Ear Length) + .46 (Ear Breadth) − 3.04

R = .78

SE of Estimate = 2.03

*Regression equation values presented in metric units only.

Percentile Values

%	*mm*	*in*
1	31.9	1.3
2	32.6	1.3
3	33.1	1.3
5	33.7	1.3
10	34.7	1.4
15	35.4	1.4
20	36.0	1.4
25	36.5	1.4
30	37.0	1.5
35	37.4	1.5
40	37.9	1.5
45	38.3	1.5
50	38.7	1.5
55	39.2	1.5
60	39.6	1.6
65	40.1	1.6
70	40.6	1.6
75	41.1	1.6
80	41.7	1.6
85	42.4	1.7
90	43.3	1.7
95	44.5	1.8
97	45.3	1.8
98	45.8	1.8
99	46.5	1.8

TRAGUS RADIUS 45°

Summary Statistics

Mean	39.1 mm	1.5 in
SE of the Mean	0.2 mm	0.0 in
Standard Deviation (SD)	3.4 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	29.9 mm - 49.8 mm	
	1.2 in - 2.0 in	
Coefficient of Variation	8.7%	
Skewness	0.20	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 45 Degrees*

.23 (Ear Length) + .82 (Ear Breadth) − 4.65

R = .86

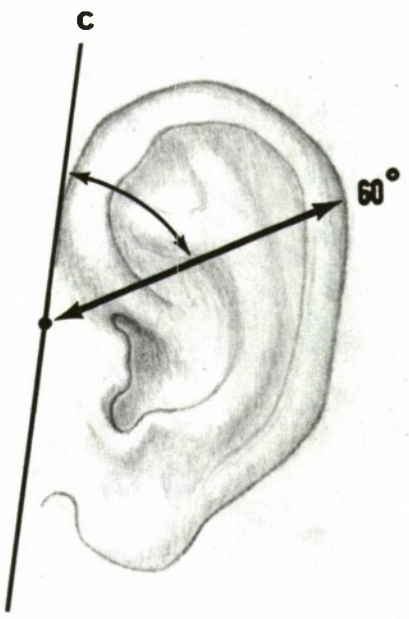
SE of Estimate = 1.74

Percentile Values

%	*mm*	*in*
1	31.3	1.2
2	32.3	1.3
3	32.8	1.3
5	33.6	1.3
10	34.7	1.4
15	35.5	1.4
20	36.1	1.4
25	36.6	1.4
30	37.1	1.5
35	37.5	1.5
40	38.0	1.5
45	38.4	1.5
50	38.8	1.5
55	39.3	1.6
60	39.7	1.6
65	40.2	1.6
70	40.7	1.6
75	41.2	1.6
80	41.9	1.7
85	42.6	1.7
90	43.5	1.7
95	44.9	1.8
97	45.7	1.8
98	46.4	1.8
99	47.3	1.9

*Regression equation values presented in metric units only.

TRAGUS RADIUS 60°



Summary Statistics		
Mean	37.4 mm	1.5 in
SE of the Mean	0.2 mm	0.0 in
Standard Deviation (SD)	3.4 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	28.4 mm - 47.8 mm	
	1.1 in - 1.9 in	
Coefficient of Variation	9.1%	
Skewness	0.20	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 60 Degrees*

.10 (Ear Length) + 1.04 (Ear Breadth) − 4.82

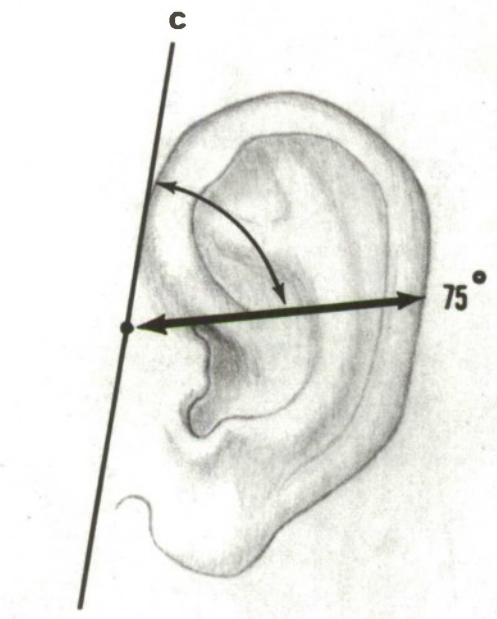
R = .93

SE of Estimate = 1.21

*Regression equation values presented in metric units only.

Percentile Values		
%	*mm*	*in*
1	29.8	1.2
2	30.5	1.2
3	31.0	1.2
5	31.7	1.3
10	32.9	1.3
15	33.7	1.3
20	34.4	1.4
25	34.9	1.4
30	35.4	1.4
35	35.9	1.4
40	36.4	1.4
45	36.8	1.5
50	37.2	1.5
55	37.6	1.5
60	38.1	1.5
65	38.5	1.5
70	39.0	1.5
75	39.5	1.6
80	40.1	1.6
85	40.8	1.6
90	41.7	1.6
95	43.2	1.7
97	44.2	1.7
98	44.9	1.8
99	46.3	1.8

TRAGUS RADIUS 75°



Summary Statistics

Mean	35.2 mm	1.4 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	3.1 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	26.9 mm - 44.8 mm	
	1.1 in - 1.8 in	
Coefficient of Variation	8.8%	
Skewness	0.12	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 75 Degrees*

.01 (Ear Length) + 1.04 (Ear Breadth) – 1.35

R = .98

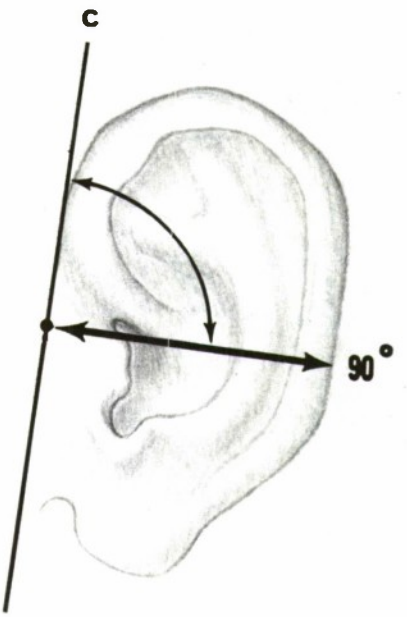
SE of Estimate = 0.65

Percentile Values

%	*mm*	*in*
1	28.1	1.1
2	28.9	1.1
3	29.4	1.2
5	30.1	1.2
10	31.1	1.2
15	31.8	1.3
20	32.4	1.3
25	32.9	1.3
30	33.4	1.3
35	33.8	1.3
40	34.2	1.4
45	34.6	1.4
50	35.0	1.4
55	35.4	1.4
60	35.8	1.4
65	36.3	1.4
70	36.7	1.5
75	37.2	1.5
80	37.8	1.5
85	38.5	1.5
90	39.3	1.6
95	40.5	1.6
97	41.2	1.6
98	41.7	1.6
99	42.5	1.7

*Regression equation values presented in metric units only.

TRAGUS RADIUS 90°



Summary Statistics

Mean	33.7 mm	1.3 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.9 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	26.4 mm - 42.3 mm	
	1.0 in - 1.7 in	
Coefficient of Variation	8.6%	
Skewness	0.11	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 90 Degrees*

$-.01$ (Ear Length) + .98 (Ear Breadth) + .61

$R = .97$

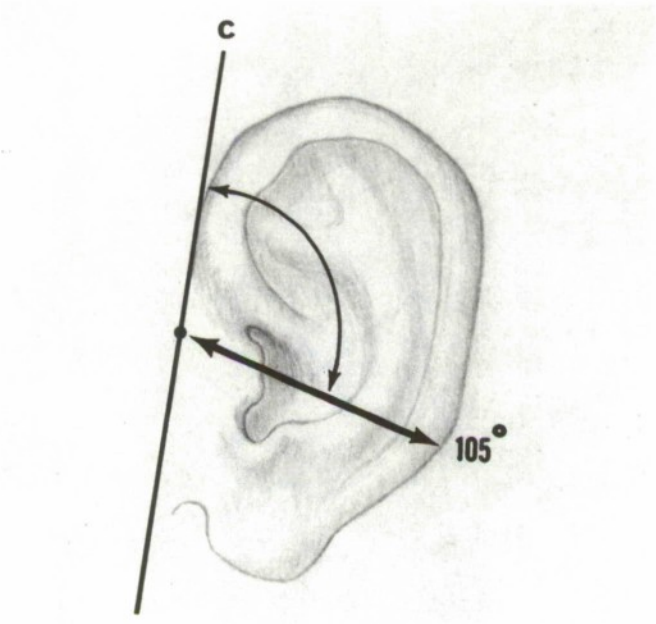
SE of Estimate = 0.69

*Regression equation values presented in metric units only.

Percentile Values

%	*mm*	*in*
1	27.0	1.1
2	27.7	1.1
3	28.2	1.1
5	28.8	1.1
10	29.8	1.2
15	30.5	1.2
20	31.0	1.2
25	31.5	1.2
30	32.0	1.3
35	32.4	1.3
40	32.8	1.3
45	33.1	1.3
50	33.5	1.3
55	33.9	1.3
60	34.3	1.4
65	34.7	1.4
70	35.1	1.4
75	35.6	1.4
80	36.1	1.4
85	36.7	1.4
90	37.4	1.5
95	38.5	1.5
97	39.2	1.5
98	39.7	1.6
99	40.5	1.6

TRAGUS RADIUS 105°



Summary Statistics		
Mean	33.0 mm	1.3 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.7 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	25.9 mm - 41.3 mm	
	1.0 in - 1.6 in	
Coefficient of Variation	8.3%	
Skewness	0.07	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 105 Degrees*

.01 (Ear Length) + .86 (Ear Breadth) + 2.66

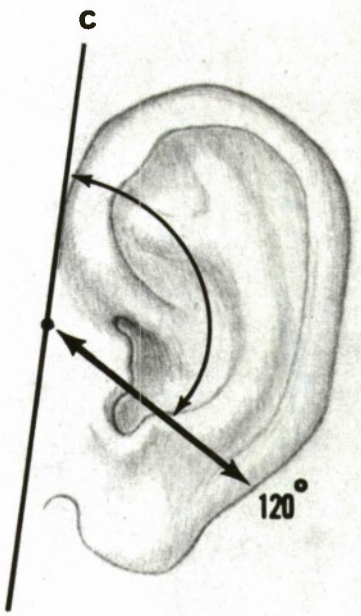
R = .93

SE of Estimate = 1.03

Percentile Values		
%	*mm*	*in*
1	27.2	1.1
2	27.5	1.1
3	27.8	1.1
5	28.3	1.1
10	29.2	1.2
15	29.9	1.2
20	30.4	1.2
25	30.9	1.2
30	31.4	1.2
35	31.8	1.3
40	32.2	1.3
45	32.6	1.3
50	32.9	1.3
55	33.3	1.3
60	33.6	1.3
65	34.0	1.3
70	34.4	1.4
75	34.8	1.4
80	35.3	1.4
85	35.8	1.4
90	36.4	1.4
95	37.4	1.5
97	38.0	1.5
98	38.5	1.5
99	39.3	1.6

*Regression equation values presented in metric units only.

TRAGUS RADIUS 120°



Summary Statistics		
Mean	33.0 mm	1.3 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.5 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	25.9 mm - 41.3 mm	
	1.0 in - 1.6 in	
Coefficient of Variation	7.7%	
Skewness	0.11	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 120 Degrees*

.08 (Ear Length) + .69 (Ear Breadth) + 3.83

R = .85

SE of Estimate = 1.32

*Regression equation values presented in metric units only.

Percentile Values		
%	*mm*	*in*
1	27.1	1.1
2	27.7	1.1
3	28.1	1.1
5	28.7	1.1
10	29.6	1.2
15	30.2	1.2
20	30.7	1.2
25	31.1	1.2
30	31.5	1.2
35	31.9	1.3
40	32.2	1.3
45	32.5	1.3
50	32.8	1.3
55	33.1	1.3
60	33.5	1.3
65	33.8	1.3
70	34.2	1.3
75	34.5	1.4
80	35.0	1.4
85	35.5	1.4
90	36.1	1.4
95	37.1	1.5
97	37.8	1.5
98	38.3	1.5
99	39.1	1.5

TRAGUS RADIUS 135°

Summary Statistics

Mean	33.5 mm	1.3 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.4 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	26.9 mm - 41.8 mm	
	1.1 in - 1.6 in	
Coefficient of Variation	7.2%	
Skewness	0.18	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 135 Degrees*

.21 (Ear Length) + .44 (Ear Breadth) + 4.23

R = .77

SE of Estimate = 1.53

Percentile Values

%	*mm*	*in*
1	27.7	1.1
2	28.5	1.1
3	29.0	1.1
5	29.6	1.2
10	30.4	1.2
15	30.9	1.2
20	31.4	1.2
25	31.7	1.3
30	32.1	1.3
35	32.4	1.3
40	32.7	1.3
45	33.0	1.3
50	33.3	1.3
55	33.6	1.3
60	33.9	1.3
65	34.2	1.4
70	34.5	1.4
75	34.9	1.4
80	35.4	1.4
85	35.9	1.4
90	36.5	1.4
95	37.5	1.5
97	38.2	1.5
98	38.7	1.5
99	39.4	1.6

*Regression equation values presented in metric units only.

TRAGUS RADIUS 150°

Summary Statistics		
Mean	34.6 mm	1.4 in
SE of the Mean	0.1 mm	0.0 in
Standard Deviation (SD)	2.8 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	26.4 mm - 42.8 mm	
	1.0 in - 1.7 in	
Coefficient of Variation	8.0%	
Skewness	0.09	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 150 Degrees*

.45 (Ear Length) + .12 (Ear Breadth) + .26

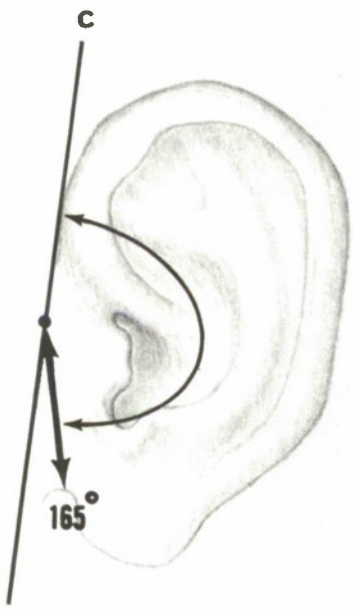
R = .78

SE of Estimate = 1.72

Percentile Values		
%	*mm*	*in*
1	27.8	1.1
2	28.8	1.1
3	29.3	1.2
5	30.0	1.2
10	31.0	1.2
15	31.6	1.3
20	32.1	1.3
25	32.6	1.3
30	33.0	1.3
35	33.3	1.3
40	33.7	1.3
45	34.0	1.3
50	34.4	1.4
55	34.7	1.4
60	35.1	1.4
65	35.5	1.4
70	35.9	1.4
75	36.3	1.4
80	36.8	1.5
85	37.4	1.5
90	38.1	1.5
95	39.2	1.5
97	39.9	1.6
98	40.4	1.6
99	41.1	1.6

*Regression equation values presented in metric units only.

TRAGUS RADIUS 165°



Summary Statistics		
Mean	32.1 mm	1.3 in
SE of the Mean	0.2 mm	0.0 in
Standard Deviation (SD)	3.6 mm	0.1 in
SE of the SD	0.1 mm	0.0 in
Range	23.9 mm - 42.8 mm	
	0.9 in - 1.7 in	
Coefficient of Variation	11.1%	
Skewness	0.25	
Sample Size	500	

Regression Equation for Predicting
Tragus Radius 165 Degrees*

.62 (Ear Length) − .39 (Ear Breadth) + 3.95

R = .73

SE of Estimate = 2.45

*Regression equation values presented in metric units only.

Percentile Values		
%	*mm*	*in*
1	24.8	1.0
2	25.4	1.0
3	25.8	1.0
5	26.4	1.0
10	27.5	1.1
15	28.2	1.1
20	28.9	1.1
25	29.4	1.2
30	30.0	1.2
35	30.5	1.2
40	30.9	1.2
45	31.4	1.2
50	31.9	1.3
55	32.3	1.3
60	32.8	1.3
65	33.3	1.3
70	33.9	1.3
75	34.4	1.4
80	35.1	1.4
85	35.9	1.4
90	36.8	1.5
95	38.2	1.5
97	39.2	1.5
98	39.9	1.6
99	40.8	1.6

SECTION VII.

Methodology for Data Application

The following information is intended to aid the designer in applying the anthropometric data presented in this report. Figure 2 indicates a scaled drawing representative of the 99th percentile ear as derived from the values determined during the PhotoMetriC study (Fig. 3 is a schematic of the 95th percentile ear). The method used to arrive as the schematic for the 99th percentile ear is as follows:

Step 1 – A line is drawn in an up-down position. The line need not be vertical.

Step 2 – A point is marked along the line drawn in Step 1. This is referred to as the *zero* point.

Step 3 – Place the zero point of a conventional protractor at the zero point marked in Step 2. The 0° - 180° line of the protractor should be superimposed on the line drawn in Step 1. Mark the angles 15° from 0° to 165°. Connect each degree marking with the zero point.

Step 4 – Measure the distance from the zero point to the desired percentile distance specified in the report. For instance, the 99th percentile value from zero point to $\measuredangle$15° is 41.7 millimeters (see page 9), $\measuredangle$30° is 46.5 millimeters (see page 10), and the $\measuredangle$45° is 47.3 millimeters (see page 11).

Step 5 – Join the measured points from angle to angle to form the clearance "contour."

The design engineer should apply appropriate allowances to clear or fit over the ear. This allowance will be influenced by the design and materials of the item being fabricated.

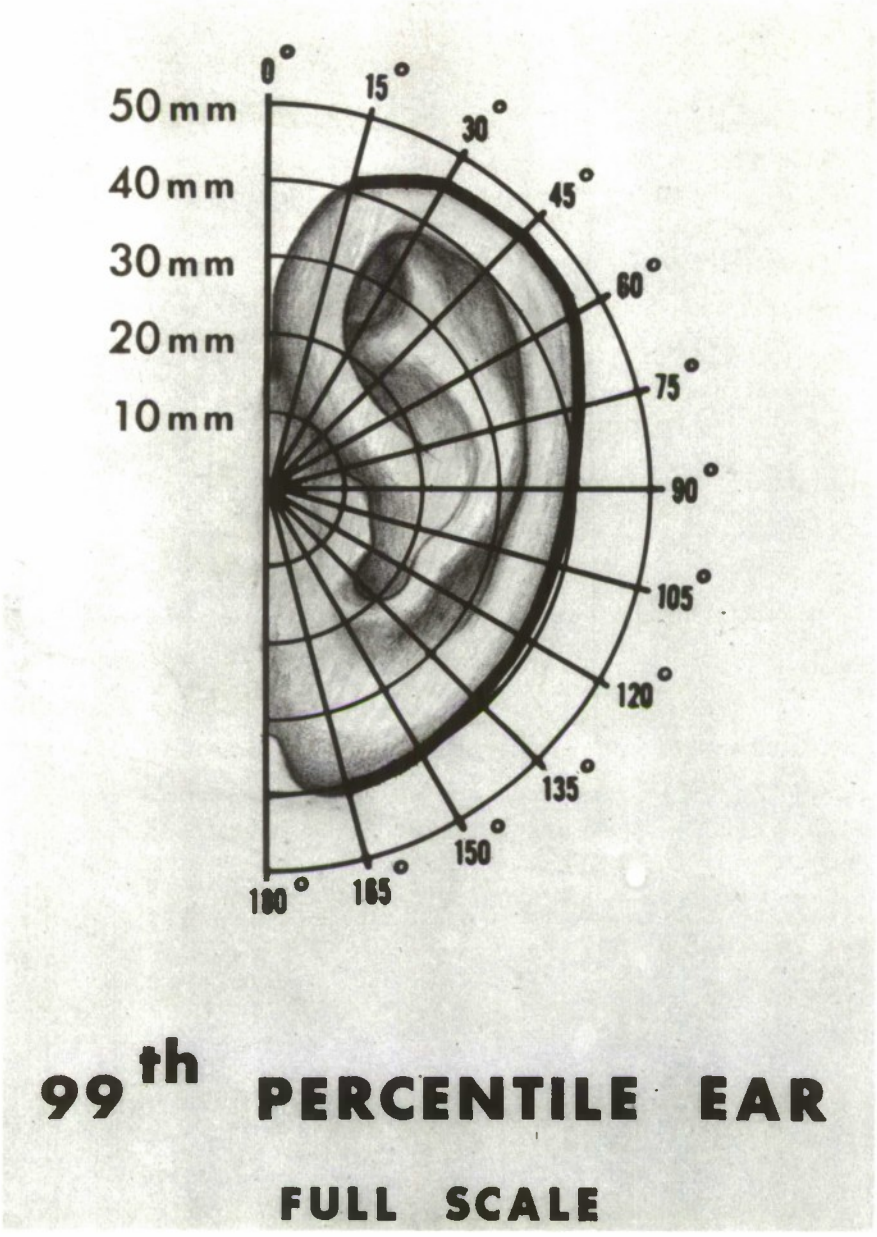
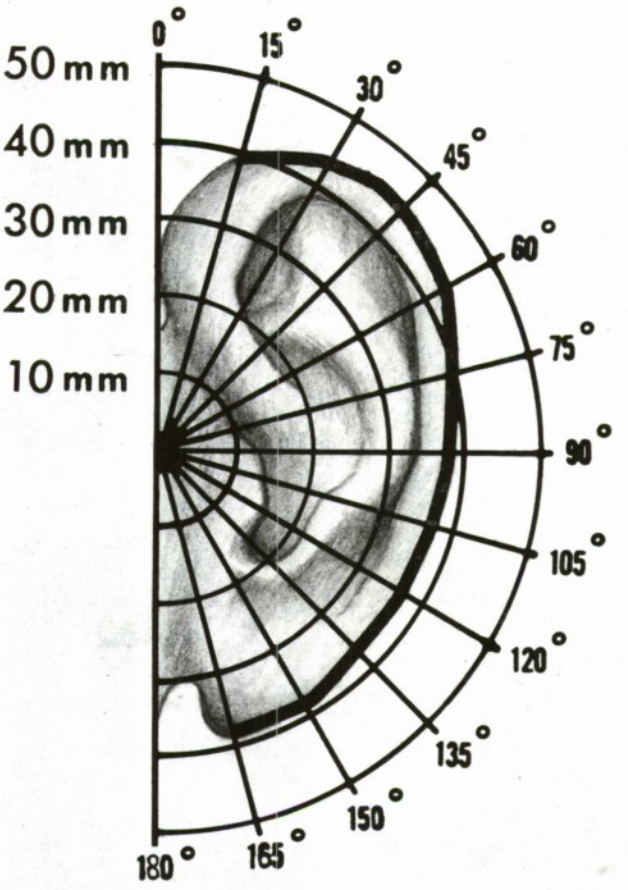


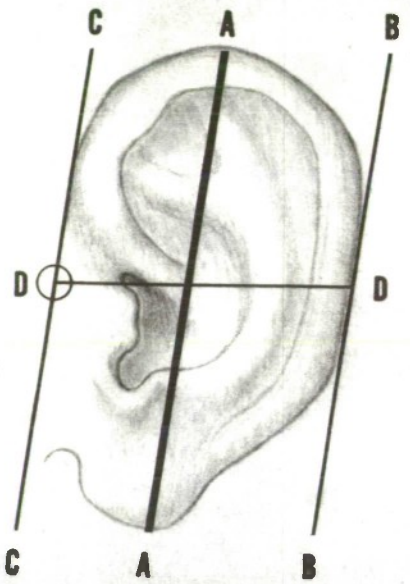
Figure 2. Schematic of 99th Percentile Ear



95th PERCENTILE EAR

FULL SCALE

Figure 3. Schematic of 95th Percentile Ear



Line A – Straight line drawn across the longest axis of the ear.

Line B – Line drawn parallel to Line A in contact with the most posterior edge of the auricula.

Line C – Line drawn parallel to Lines A and B in contact with the most anterior edge of the helix.

Line D – Horizontal line drawn across the auricula and intersecting Line C at the level of landmark Tragion.

Baselines Used for Various Ear Clearance Dimensions

APPENDIX

Reliability of Measurements

To determine the reliability[1] and objectivity[2] of the measuring technique used in this study a random sample of 50 slides were selected from the 2236 slides in the entire sample. The reliability of the technique was shown by having the two investigators measure the same slide on two different occasions. These results are shown in tables II and III of the appendix. The objectivity of the technique was determined by computing correlation coefficients between the two averaged values of both investigators. These results are shown in table IV of the appendix. Their derived coefficients of correlation met the predetermined criterion ($r \geq .80$) for both the reliability and objectivity measurements.

The mean age of the test sample was 27.82 years, standard deviation of 4.70; mean Stature was 176.01 centimeters, standard deviation of 5.51; mean Weight of 75.53 kilograms, standard deviation of 9.37.

TABLE II

TEST-RETEST RELIABILITY COEFFICIENTS*

	Investigator I						
	Reading 1				Reading 2		
	M	*SD*	*CV %*	*Reliability Coefficient*	*M*	*SD*	*CV %*
Ear Length	66.2	4.4	6.6	.88	66.4	4.6	6.9
Ear Breadth	34.1	3.3	9.7	.85	33.9	3.5	10.3
Ear Length Above Plane of Tragion	30.5	3.4	11.1	.91	31.4	2.5	8.0
Tragus Radius 15°	33.9	3.6	10.6	.92	34.2	3.3	9.6
Tragus Radius 30°	37.7	3.8	10.1	.91	37.9	3.4	9.0
Tragus Radius 45°	38.3	3.7	9.7	.88	38.1	3.4	8.9
Tragus Radius 60°	36.9	3.5	9.5	.85	36.7	3.5	9.5
Tragus Radius 75°	35.2	3.2	9.1	.88	34.7	3.6	10.4
Tragus Radius 90°	33.9	3.0	8.8	.86	33.3	3.4	10.2
Tragus Radius 105°	33.5	2.6	7.8	.83	32.9	3.1	9.4
Tragus Radius 120°	33.5	2.7	8.1	.82	33.0	2.8	8.5
Tragus Radius 135°	33.8	2.7	8.0	.87	33.5	2.9	8.7
Tragus Radius 150°	34.8	2.9	8.3	.83	34.2	3.0	8.8
Tragus Radius 165°	32.1	4.0	12.5	.85	31.7	3.9	12.3

*Number of subjects is 50; all dimensions are in millimeters. The CV % (coefficient of variation) is a restatement of the standard deviation expressed as a percentage of the mean: CV = (100.0 x SD/M) %.

[1]Reliability is defined by Rogers (ref 10) as: "a measure is reliable if two or more *measurements* of the same object or function by the same measuring device yield similar scores."

[2]Objectivity is defined by Rogers (ref 10) in the following manner: "a measure is objective if two or more different *individuals*, using the same instrument, or procedure, secure similar results."

TABLE III

TEST-RETEST RELIABILITY COEFFICIENTS*

	Investigator II						
	Reading 1				Reading 2		
	M	*SD*	*CV %*	*Reliability Coefficient*	*M*	*SD*	*CV %*
Ear Length	66.1	4.6	7.0	.93	65.9	4.6	7.0
Ear Breadth	35.9	2.7	7.5	.88	35.3	3.2	9.1
Ear Length Above Plane of Tragion	31.1	2.6	8.4	.87	31.7	2.6	8.2
Tragus Radius 15°	34.7	3.2	9.2	.85	35.2	3.0	8.5
Tragus Radius 30°	39.1	3.5	9.0	.83	39.5	3.3	8.4
Tragus Radius 45°	39.6	3.5	8.8	.87	39.7	3.3	8.3
Tragus Radius 60°	38.4	3.1	8.1	.83	38.1	3.3	8.7
Tragus Radius 75°	36.4	2.9	8.0	.87	35.9	3.3	9.2
Tragus Radius 90°	34.7	2.7	7.8	.87	34.2	3.1	9.1
Tragus Radius 105°	33.7	2.4	7.1	.84	33.4	2.9	8.7
Tragus Radius 120°	33.7	2.3	6.8	.81	33.2	2.5	7.5
Tragus Radius 135°	33.8	2.3	6.8	.83	33.4	2.6	7.8
Tragus Radius 150°	34.4	2.6	7.6	.87	33.6	3.0	8.9
Tragus Radius 165°	31.8	3.5	11.0	.85	31.6	3.4	10.8

*Number of subjects is 50; all dimensions are in millimeters. The CV % (coefficient of variation) is a restatement of the standard deviation expressed as a percentage of the mean: CV = (100.0 x SD/M) %.

TABLE IV

TEST-OBJECTIVITY COEFFICIENTS*

	Investigator I				Investigator II		
	M	*SD*	*CV %*	*Reliability Coefficient*	*M*	*SD*	*CV %*
Ear Length	66.3	4.4	6.6	.90	66.0	4.5	6.8
Ear Breadth	34.0	3.3	9.7	.86	35.6	2.9	8.1
Ear Length Above Plane of Tragion	30.9	2.9	9.4	.80	31.4	2.5	8.0
Tragus Radius 15°	34.1	3.4	10.0	.80	35.0	3.0	8.6
Tragus Radius 30°	37.8	3.5	9.3	.82	39.3	3.3	8.4
Tragus Radius 45°	38.2	3.4	8.9	.84	39.7	3.3	8.3
Tragus Radius 60°	36.8	3.4	9.2	.88	38.3	3.1	8.1
Tragus Radius 75°	34.9	3.3	9.5	.86	36.2	3.0	8.3
Tragus Radius 90°	33.6	3.1	9.2	.86	34.4	2.8	8.1
Tragus Radius 105°	33.2	2.7	8.1	.83	33.6	2.6	7.7
Tragus Radius 120°	33.3	2.6	7.8	.80	33.4	2.3	6.9
Tragus Radius 135°	33.7	2.7	8.0	.80	33.6	2.3	6.8
Tragus Radius 150°	34.5	2.9	8.4	.80	34.0	2.7	7.9
Tragus Radius 165°	31.9	3.8	11.9	.84	31.7	3.3	10.4

*Number of subjects is 50; all dimensions are in millimeters. The CV % (coefficient of variation) is a restatement of the standard deviation expressed as a percentage of the mean: CV = (100.0 x SD/M) %.

TABLE V

INTERCORRELATION MATRIX

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
1.	—	.277	.086	.354	.170	.121	.075	.143	.166	.178	.171	.168	.189	.235	.343	.423	.324
2.	.277	—	.463	.396	.278	.285	.291	.343	.333	.291	.269	.279	.276	.286	.327	.339	.240
3.	.086	.463	—	.362	.173	.308	.317	.298	.258	.209	.180	.167	.153	.187	.215	.262	.205
4.	.354	.396	.362	—	.357	.720	.718	.679	.557	.440	.365	.335	.349	.426	.589	.771	.667
5.	.170	.278	.173	.357	—	.314	.299	.604	.809	.927	.978	.971	.926	.843	.678	.387	−.036
6.	.121	.285	.308	.720	.314	—	.855	.766	.588	.431	.338	.294	.278	.290	.335	.348	.171
7.	.075	.291	.317	.718	.299	.855	—	.868	.663	.470	.326	.249	.205	.184	.208	.216	.138
8.	.143	.343	.298	.679	.604	.766	.868	—	.912	.767	.634	.549	.484	.436	.398	.295	.007
9.	.166	.333	.258	.557	.809	.588	.663	.912	—	.937	.838	.758	.679	.608	.516	.323	−.066
10.	.178	.291	.209	.440	.927	.431	.470	.767	.937	—	.951	.891	.817	.732	.595	.344	−.084
11.	.171	.269	.180	.365	.978	.338	.326	.634	.838	.951	—	.969	.903	.811	.648	.368	−.057
12.	.168	.279	.167	.335	.971	.294	.249	.549	.758	.891	.969	—	.959	.875	.707	.407	−.017
13.	.189	.276	.153	.349	.926	.278	.205	.484	.679	.817	.903	.959	—	.943	.789	.480	.056
14.	.235	.286	.187	.426	.843	.290	.184	.436	.608	.732	.811	.875	.943	—	.905	.612	.199
15.	.343	.327	.215	.589	.678	.335	.208	.398	.516	.595	.648	.707	.789	.905	—	.818	.428
16.	.423	.339	.262	.771	.387	.348	.216	.295	.323	.344	.368	.407	.480	.612	.818	—	.739
17.	.324	.240	.205	.667	−.036	.171	.138	.007	−.066	−.084	−.057	−.017	.056	.199	.428	.739	—

LEGEND:

1. Age
2. Weight
3. Stature
4. Ear Length
5. Ear Breadth
6. Ear Length above Plane of Tragion
7. Tragus Radius 15°
8. Tragus Radius 30°
9. Tragus Radius 45°
10. Tragus Radius 60°
11. Tragus Radius 75°
12. Tragus Radius 90°
13. Tragus Radius 105°
14. Tragus Radius 120°
15. Tragus Radius 135°
16. Tragus Radius 150°
17. Tragus Radius 165°

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Security Classification

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13. ABSTRACT

A technique was developed that enables precisely specified ear dimensions to be measured directly from PhotoMetriC slides. Summary statistics for each of the various ear dimensions are presented for a sample of 500 subjects randomly chosen from a total series of 2236 photographic slides collected during the 1957 Authropometric Survey of USAF Male Flying Personnel. Regression equations for predicting the various ear dimensions from Ear Length and Ear Breadth are presented. A complete intercorrelation matrix for all variables studied in this research is also shown. The reliability and objectivity of the technique are discussed.

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